(54) Title: LOCATING MOBILE UNITS IN A CELLULAR TELEPHONE SYSTEM VIA VIRTUAL LOCATION AREAS
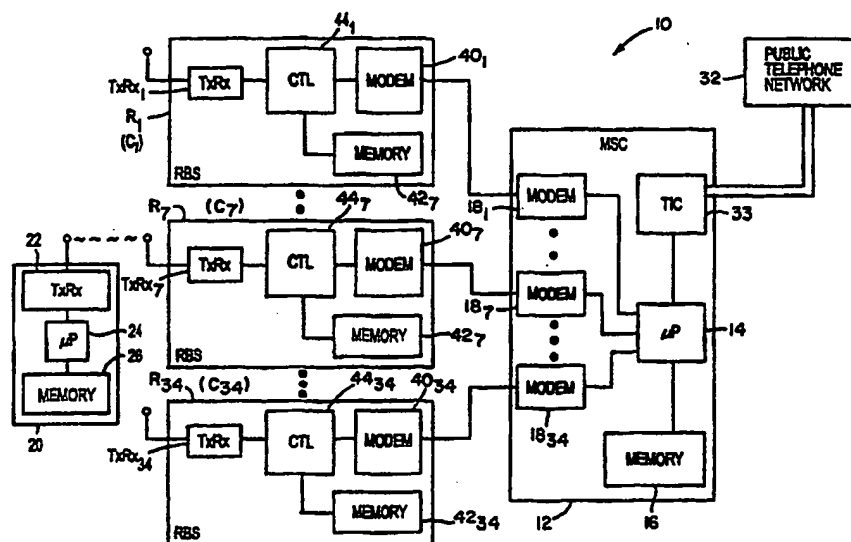
(57) Abstract

A method and system for identifying the location of mobile units (20) within a cellular telephone system (10). A subset of cells is dynamically assigned to a mobile unit based upon the cell location of the mobile unit at the time of registration. The mobile unit records the subset information, and as long as the mobile unit remains in one of the cells in the subset, it does not re-register its location with the system. The system is able to locate the mobile unit within the assigned subset of cells. When the mobile unit enters a new cell that is not within the subset of cells, it re-registers with the system which then assigns a new subset of cells corresponding to its location within a new cell that did not belong to the previous subset.

LOCATING MOBILE UNITS IN A CELLULAR TELEPHONE SYSTEM VIA VIRTUAL LOCATION AREAS

FIELD OF THE INVENTION

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The invention relates generally to mobile communication systems, and in particular to a system and method for locating mobile units within a cellular telephone system.

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BACKGROUND OF THE INVENTION

In typical cellular radio telephone systems, the area served is divided into hexagonal cells wherein each cell is defined by a radio base station (RBS) having a

15 plurality of transceivers for communicating both control and voice information with mobile units, i.e., mobile telephones. As long as a mobile unit is powered-up within the broadcast range of any RBS defining a cell of the system, the mobile unit is capable of initiating and

20 receiving calls. A centralized mobile switching center (MSC) connected to all of the RBSs connects the mobile unit's outgoing and incoming calls to and from the public telephone network and to other mobile units.

When a mobile unit initiates a call in a system, it

25 uses a control channel (i.e., a reserved carrier frequency) assigned to the RBS that defines the local cell in which it is currently located. When any two-way communication between the mobile unit and the RBS takes place on that particular control channel, the identity of

30 the cell in which the mobile unit is currently located is known to the system. To handle voice communication, the system generally assigns a voice channel from a plurality of RBS transceivers available in the same cell that corresponds to the control channel.

35 While engaged in a call, the mobile unit often moves beyond the broadcast range of the current cell into the broadcast range of another cell. In this case, the system ordinarily transfers the mobile unit to a voice

chann 1 available in the new cell. Accordingly, while
engaged in a call the system knows the current cell
location of a mobile unit.

Even while not engaged in a call, an activated
5   mobile unit receives information sent by the system on
the control channel of the cell in which the mobile unit
is currently located. When the mobile unit moves beyond
the broadcast range of the current control channel, it is
designed to search for and re-tune its receiver to the
10 control channel of the cell serving the mobile unit's new
location. However, as the mobile unit moves from one
cell to another it typically does not transmit
information to the new cell. The system therefore does
not know the current cell location of a mobile unit that
15 is neither engaged in a call nor in the process of
initiating a call.

Accordingly, when an incoming call arrives at the
MSC for a mobile unit, the MSC ordinarily does not know
the current cell location of the mobile unit nor does it
20 know the cell control channel to which the mobile unit is
currently tuned. In order to determine the cell in which
the mobile unit is currently located, the MSC sends
control information addressed to that mobile unit on the
control channel of every cell in which the mobile unit
25 could possibly be located. When the mobile unit
recognizes its address on the control channel to which it
is currently tuned, it responds to the system on the
control channel of that cell and thereby notifies the
system of the cell that is currently serving the mobile
30 unit. In other words, the MSC pages the cells of the
system until the mobile unit is located.

Although locating a mobile unit by sending
information to the mobile unit on the control channel of
every cell is an acceptable procedure in systems serving
35 a small number of mobile units, this procedure becomes
very inefficient as the number of mobile units increases
and the number of cells increases to serve larger

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geographic areas or to provide more call capacity. At
some point, the capacity of the control channels becomes
exhausted due to a large portion of that capacity being
used in an attempt to locate mobile units, even though
5   each mobile unit is only present within one of the many
cells of the system at any given time.

    To overcome this capacity problem, current systems
employ several techniques to attempt to reduce the number
of cells into which this redundant information must be
10   sent. These methods are all directed to methods of
determining the probable location of the mobile unit
within a subset of all possible cells by having the
mobile unit report its location even if it does not need
to communicate with the system for other purposes such as
15   originating a call. By way of example, two such methods
include 1) periodic or time-based notification, and 2)
location-based notification. In addition, both of these
methods may be combined with notification (of the mobile
unit's presence in the system) on power-up and power-down
20   of the mobile unit to reduce attempts to locate mobile
units that are not currently powered-up in any cell of
the system.

    In the time-based notification method, the system
sends information on the control channel of each cell
25   indicating when one or more of the mobile units should
notify the system of their location. The system can then
determine the probable location of a mobile unit based on
the time and location of the last report and the
anticipated rate of movement. This method is
30   particularly effective in systems covering very large
areas with large cells. However, when the cells are
relatively small or the rate of movement is relatively
fast, the time interval between reports must be shortened
to accommodate the frequent cell location changes. As a
35   result, the proportion of location reports to incoming
calls increases, thereby burdening the system with
frequent, unnecessary reports which tend to overload the

available control channels. This method als burdens the
system with periodic reports from mobile units that have
not changed their location.

In the location-based reporting method, cell
5 identification information is sent by each cell on its
control channel. The mobile unit reports its location
whenever it moves to a cell control channel that is
sending different cell location identification
information. One well-known type of cell identification
10 occurs when a mobile unit moves from one cellular system
to a different system, and the mobile unit receives the
system change information and reports its location to the
new system.

One technique for location-based reporting within
15 the same system includes transmitting location
information common to a fixed group of cells, i.e., to a
subset of the total number of cells grouped into fixed
location areas. Typically, the cells are geographically
organized into groups of cells having fixed grouping
20 boundaries. In this case, each fixed group of cells
typically transmits the same group location
identification to mobile units therein. When a mobile
unit moves from one group location to another, it reports
its new group location to the system. With this method
25 mobile units report their location only when and if they
move from the previously reported group location, thereby
eliminating unnecessary location reports and allowing the
system to know the mobile unit's location to within a
fixed group of cells.

30   The number of fixed location areas, and the number
of cells in each location area can be adjusted to balance
the overhead of registrations (caused by the mobile
unit's movement and resultant reporting) against the
overhead of paging multiple cells of the group. In other
35 words, as a fixed group increases in the number of cells
that comprise it, the greater the amount of paging
required to find the mobile unit within its current

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group, while as a fixed group decreases in the number of
c lls that comprise it, the greater the amount of
location reporting resulting from more numerous and
frequent crossings of the fixed boundaries.

5   While this system is often able to reduce the system
overhead by reducing the total amount of paging in
exchange for location reporting, problems arise since the
location areas are defined by a set of cells sending
common location identification to all mobile units
10   receiving the control channels of these cells.

        By way of example, when two adjacent cells in
different fixed location areas are sending different
location identification information across a fixed
boundary, the mobile unit will report its location each
15   time it moves from one cell to the other. Since a mobile
unit may repeatedly move between cells in a short period
of time, the number of location reports will be
excessive. In addition, such numerous registrations tend
to quickly drain the batteries on certain types of mobile
20   units (for example, hand-held mobile units with a self-
contained power source as opposed to mobile units powered
by car batteries) since signal transmission ordinarily
consumes more power than does signal reception.

        Moreover, substantial problems can arise when the
25   mobile unit travels across boundaries of different
systems. Essentially, different adjacent systems are
somewhat analogous to fixed location areas in that the
mobile unit must report its location to the new system
upon entry in order to be found by the MSC that receives
30   its incoming calls.

        For example, when a mobile unit changes systems,
such as when moving from a "home" system to a "foreign"
system, the foreign system may be arranged to report the
presence of the mobile unit therein to the home system.
35   In this manner, the home system is able to forward
incoming calls to the foreign system. However, there is
often a time delay between the time that the mobile unit

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actually enters the foreign system and the time that the
home system receives notification of the mobile unit's
presence therein. If the mobile subsequently reenters a
cell in the home system during this time delay, i.e.,
5   prior to the home system receiving the notification, it
re-registers its presence with the home system. When the
home system later receives the notification from the
foreign system, the home system concludes that the mobile
unit has moved into a cell of the foreign system when in
10   actuality it has just returned. In essence, under these
circumstances the location reports are received out of
sequence, thereby resulting in the recording of incorrect
location information. This results in the mobile unit
being "lost" to the home system until a subsequent
15   location registration takes place.

SUMMARY OF THE INVENTION

Accordingly, it is a primary object of the invention
to provide a method and system for reducing system
20   overhead while balancing the amount of paging against the
number of registrations.

It is another object of the present invention to
provide a method and system as characterized above to
locate mobile units within a virtual subset of cells that
25   varies dynamically.

Another related object of the invention is to
provide a method and system of the above kind wherein
each mobile unit has its own virtual location.

It is another object to provide a method and system
30   of the above kind wherein the system realigns the subset
of cells corresponding to each cell to optimize system
needs.

Still another object is to provide such a method and
system wherein the virtual subset groupings are broadcast
35   to the mobile units.

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Another object is to pr vide such a method and
system wherein the virtual subset groupings are
standardized within the mobile units.

It is yet another object of the invention to provide
5   a method and system that facilitates location reporting
as mobiles travel between different systems.

It is another object of the invention to minimize
the coordination required between different systems of
cells when locating mobile units in one of the systems.

10   Briefly, the invention provides a method and system
for locating a mobile unit within a dynamic subset of all
of the cells of the system. To this end, information
identifying the cell is transmitted from each of the
cells in the system, and is received at the mobile unit

15   from a local one of the cells that is the cell within
which the mobile unit is located. A transceiver at each
RBS is employed to transmit the cell identifying
information to a transceiver at the mobile unit.

The received cell identity is then compared with the
20   identity of a subset of all of the cells stored in a
memory to determine if the identity of the local cell
matches the identity of one of the cells in the subset.
If there is not a match, the mobile unit registers its
location by transmitting information from the mobile unit

25   to the RBS of the local cell to identify and report the
presence of the mobile unit within the local cell. The
RBS then communicates information to the MSC that locates
the mobile unit within the local cell and within the new
subset of cells. The identity of the subset of cells

30   stored in the memory is updated with the identities of
the cells of a new subset that includes the local cell.
A processor is preferably employed to compare the
identities of the subset of cells in the memory with the
identity of the local cell, and circuitry responsive to

35   the processor informs the RBS of the local cell that the
mobile unit is within the cell and also updates the
identities of the cells in the subset of cells stored in

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the memory. The subset is alternatively known as a virtual mobile location area, or the acronym VMLA.

Other objects and advantages will become apparent from the following detailed description when taken in conjunction with the drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates a prior art cellular system wherein subsets of cells are grouped into fixed location areas;

Fig. 2 illustrates two adjacent cellular systems;

Fig. 3a is a block diagram illustrating the key components of the cellular system according to the invention;

Fig. 3b is a pair of state machine diagrams (i) and (ii) representing functions performed by the mobile unit and MSC processing circuitry of Fig. 3a in accordance with received and stored data;

Fig. 4 is a representation of a cellular system according to the invention wherein a subset of cells is dynamically assigned to a mobile unit and recorded as its virtual location area;

Fig. 5 is a representation of a cellular system according to the invention wherein a mobile unit has traveled to a different cell within the subset of cells assigned in Fig. 4;

Fig. 6 is a representation of a cellular system according to the invention wherein a mobile unit has traveled to a different cell out of the subset of cells assigned in Fig. 4 and is assigned a new subset of cells as its virtual location area;

Fig. 7 is a representation of an MSC memory area reserved for storing the last reported location of a mobile unit in a cell of the system;

Fig. 8 is a representation of an MSC memory area reserved for storing the subset information corr sponding to each cell of the system;

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Fig. 9 is a table of the cell location identification (CLI) codes and system id ntification (SI) codes broadcast by the RBSs defining the cells of the system to mobile units therein;

5   Fig. 10 is a table of the CLI codes and their corresponding cell identities;

Fig. 11 is a representation of the contents of a section of mobile unit memory reserved for recording virtual location subset information;

10   Fig. 12 is a flow diagram of the mobile unit software functions for implementing the invention;

Fig. 13 is a flow diagram of the MSC software functions for implementing the invention;

Figs. 14a-14c are representations of the memory 15   contents reserved for recording standardized subset information; and

Figs. 15a-15c are representations of a cellular system corresponding to Figs. 14a-14c illustrating standardized virtual locations for one of the cells of a 20   system.

While the invention is susceptible of various modifications and alternative constructions, certain illustrated embodiments thereof have been shown in the drawings and will be described below in detail. It 25   should be understood, however, that there is no intention to limit the invention to the specific forms disclosed, but on the contrary, the intention is to cover all modifications, alternative constructions, and equivalents falling within the spirit and scope of the invention.

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DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Figs. 1 and 2 show two systems wherein the cells are subdivided into fixed location groupings. Fig. 1 represents the prior art of dividing groups of cells into 35   fixed location areas within a single cellular system, while Fig. 2 illustrat s two diff rent, but adjacent systems having a fixed boundary therebetwe n. In the

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fixed location areas of Fig. 1 and the adjacent systems
illustrated in Fig. 2, as mobile units travel across
these fixed boundary lines, the previously described
problems associated therewith (i.e., excessive location
5   reporting, location reports received out-of-sequence, and
so on) adversely affect mobile communications.

Turning now to Figs. 3a-4, there is shown a cellular
telephone system according to the invention generally
designated 10 having a plurality of cells C_1-C_{34},
10   corresponding to radio base stations (RBSs) R_1-R_{34}
connected to a mobile switching center (MSC) 12. It is
to be understood that conventional input-output circuitry
allowing both voice and data communication between the
MSC 12 and each RBS R_1-R_{34} defining a cell C_1-C_{34} are
15   present. Moreover, it can be readily appreciated that
the system of cells may be of any number and be arranged
in any desired pattern, and is in no way intended to be
limited to the thirty-four cells as illustrated.

As in conventional systems, the mobile unit 20 has a
20   transceiver (TxRx) 22 for communicating with at least one
transceiver (TxRx) such as transceiver $TxRx_7$ of the RBS R_7
(corresponding to cell C_7) on a reserved control channel
and an assigned voice channel when appropriate.
Additionally, the mobile unit 20 comprises conventional
25   circuitry including a processor 24 and memory 26. The
MSC 12 also has processing circuitry such as
microprocessor 14 and at least one memory storage area 16
associated therewith.

The MSC 12 and the RBSs R_1-R_{34} transfer control data
30   between MSC modems 18_1-18_{34} and RBS modems 40_1-40_{34}. To
control the operation of the RBSs, conventional system
controllers (CTLs) 44_1-44_{34}, which may be microprocessors
or the like, and memories 42_1-42_{34} are ordinarily
incorporated therein.

35   In accordance with one aspect of the invention, any
time that a mobile unit (such as the mobile unit 20) is
actively receiving signals from any RBS in the system,

the mobile unit 20 occupies a virtual location area
associat d with its current c 11. As best shown in Fig.
4, the mobile unit 20 is currently within cell C_7. The
virtual location area 30 (indicated by cross-hatching)
comprises a subset group of cells defined for the current
cell C_7 that the mobile unit is within at the time of
registration with the system.

Like cell C_7, every other cell of the system may
have a subset group of cells previously assigned to it
(preferably by the MSC 12) so that whenever a mobile unit
registers its presence within a particular cell, the MSC
12 is able to access its memory 16 to determine the
identities of the other cells in that particular cell's
subset group. When a call is received, the MSC 12 only
needs to page the cells of the subset group to locate the
mobile station. Thus, in the illustrated embodiment, as
described in more detail below, once registered with the
cell C_7, the MSC 12 at most only needs to page cells C_3,
C_4, C_6, C_7, C_8, C_{11}, C_{12} and C_{16} to locate the mobile unit
20. This paging of the subset cells may either be done
simultaneously or sequentially until the mobile unit 20
is located.

In accordance with one feature of the invention, to
facilitate the paging of the cells, each cell C_1-C_{34} is
provided by the MSC 12 with a cell location identifying
label (CLI) that may or may not be unique to each cell.
As a result of this feature, the amount of information
that must be transmitted from an RBS to the mobile unit
is reduced, since rather than broadcasting an identifier
for (i.e., the identity of) each individual cell in the
subset, one or more cells may be assigned the same
identifying CLI code. As best shown in Figs. 4, 9 and
10, cells C_1 and C_2 have commonly been assigned a CLI
equal to 06, cells C_3 and C_7 have commonly been assigned a
CLI equal to 02, and so on. As can be readily
appreciat d, unless reorganized at a later time by th
MSC 12, cells C_1 and C_2 will always be paired together

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wh never these cells belong to a subset group of cells
for a particular mobile unit since their CLIs are
identical. Note that cell C_6 has been singularly
assigned a CLI equal to 05.

5   Thus, although not necessary to the invention since
the individual cell numbers can alternatively be
transmitted as the identity of the cell, this CLI coding
feature reduces the amount of subset information that
must be transmitted to a mobile unit when it registers in
10   a new cell, as more than one cell in the subset can be
identified with a single code number (i.e., the CLI). It
can also be appreciated that this feature only adds to
the flexibility of the system, since the MSC 12 can
always assign each individual cell to a unique CLI if
15   necessary, (although this will correspondingly increase
the amount of information that must be transmitted as
described previously).

          To facilitate the understanding of the invention,
the operation of the system will now be described with
20   primary reference to Figs. 4-6 wherein a single mobile
unit initially becomes operational in cell C_7 (Fig. 4),
travels to cell C_6 (Fig. 5) and thereafter enters cell C_5
(Fig. 7).

          As shown in the exemplified embodiment of the Figs.
25   3a-11 and the flowchart Fig. 12, the system functions as
a mobile station 20 becomes active in a cell (such as the
cell C_7) of the system, for example by being powered-up
by a subscriber in that cell. At the time of power-up,
the section 26a of the mobile unit memory 26 (see Fig.
30   11) that is reserved for storing subset information is
cleared, either by action taken during the power-up
procedure itself or because the memory is cleared as a
result of the previous powering-down of the unit 20. Of
course, it can be readily appreciated that at the time of
35   powering-up, as part of its power-up procedure the mobile
unit 20 can immediately register itself to the current
cell C_7 of the system that it is within, however it can

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also initially register with the system by acting in
accordance with the invention as described below.

        As shown in the flowchart of Fig. 12, at step 100
the mobile unit 20 regularly receives (on the control
channel of the RBS R_7 corresponding to cell C_7) the CLI
number assigned to cell C_7, a CLI equal to "02" and a
system identifier (SI), an "A" code (see Fig. 9). The
mobile unit 20 ordinarily takes no action unless a cell
change has been detected (i.e., either during power-up or
when the mobile re-tunes its transceiver to a new control
channel). When a change in cells is detected, as
indicated at step 102 of Fig. 12 and as represented by
the state machine in part (i) of Fig. 3b, the mobile unit
processor compares the received CLI ($CLI_{(r)}$ = 02) with the
contents ($CLI_{(list)}$) of its subset cell storage area in
the memory 26a. The comparison determines if the new
cell has an identifier matching a cell identifier in the
previously assigned subset group that was received when
the mobile unit registered in the cell C_7, i.e., if $CLI_{(r)}$
equals a CLI stored in $CLI_{(list)}$. Since the memory 26a is
initially clear (not shown), no match is found at step
102 and as a result the mobile unit 20 clears its memory
section 26a (which initially is already clear) at step
110 and reports its location to the system by
transmitting information to the RBS R_7 of cell C_7 at step
112. At this point, at step 114 the mobile unit 20
receives and stores in the memory 26a the new CLI list
for the subset of cells grouped with current cell C_7
(Fig. 11). In this example, the CLI list consists of CLI
numbers 02 (for cells C_3 and C_7), 05 (for cell C_6), 03
(for cell C_{11}), 04 (for cells C_{12} and C_{16}) and 01 (for
cells C_4 and C_8), i.e., $CLI_{(list)}$ = 02, 05, 03, 04 and 01.
Figure 10 shows the CLI numbers and their corresponding
cells for the exemplified embodiment.

        As shown in Fig. 7 and in st ps 120 and 122 of Fig.
13, the MSC 12 receives from the RBS R_7 and records in an
MSC memory area 16a the identity of the mobile unit 20

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(equal to M20) in conjunction with the pr sent cell
(equal to C_7) that the mobile unit 20 is within. In a
further MSC memory area 16b (Fig. 8), the MSC 12 has
previously recorded the subset information for each cell
5   by storing the CLI list for each cell. Thus, as shown,
in MSC memory area 16b, cell C_7 has as its corresponding
virtual memory location area cells having CLI numbers 02,
05, 03, 04 and 01 as also indicated by the subset of
cells of Fig. 4. The list is equivalent to the list
10   stored in the mobile unit memory section 26a as described
above.

At steps 124 and 126, the MSC retrieves the CLI list
for cell C_7 and sends it through the RBS R_7 to the mobile
unit 20. The retrieval step may be accomplished as
15   represented in the state machine diagram of part (ii) of
Fig. 3b by comparing the cell identity C_7 with a list of
cells in memory to find the memory location of the
appropriate CLI list or by otherwise indexing the memory
using cell C_7. Of course, it can be readily appreciated
20   that rather than retrieve and transmit the list for each
registration, to reduce data transmission the MSC 12 may
have previously downloaded the appropriate CLI list to
each RBS R_1-R_{34} of the system which records it in its
memory 42_1-42_{34}. It can also be appreciated that if the
25   MSC needs to realign or update the cell groupings, a
subsequent and similar downloading procedure is then
executed. Further, it should be understood that the CLI
list may be different for different mobiles as described
below, (for example based on subscription type), and
30   therefore with an MSC to RBS downloading procedure the
RBS may have to select from among multiple lists, either
by its making its own determination or by direction from
the MSC. In any case, the RBS transfers the proper CLI
list to the mobile unit.

35   After receiving the CLI subset list for cell C_7, the
mobile unit 20 returns to step 100 and either waits until
a new cell is entered or alternatively continues to

execute the st ps symboliz d in Fig. 12 while remaining
within th cell C_7. However, unlike the time of th
initial comparison when the mobile unit memory area 26a
was cleared, the subsequent time that the mobile unit 20
5   receives a CLI equal to "02" at step 100, the mobile unit
will find a match at step 102 since a "02" is stored in
the memory area 26a. Accordingly, the procedure then
branches to a different routine in order to compare the
current system identifier (SI_s) with the received system
10 identifier (SI_r) to ensure that the mobile has not moved
into a cell of another system that happens to have a CLI
number matching the stored list. The system comparisons
are described in more detail below, however for now it is
sufficient to recall that since the mobile unit is still
15 in the same cell C_7, the mobile cannot have entered into
a new system of cells, and thus no subsequent
registration occurs.

As shown in Fig. 5, as the mobile unit 20 travels to
a new cell C_6, again at step 100 it begins to receive
20 cell C_6's CLI code equal to "05" along with an SI code
"A" (see Fig. 9). Since it has entered a new cell, at
step 102, it compares the "05" with the CLI list in its
reserved memory area 26a. Since cell C_6 is in the
virtual location area defined for cell C_7, the CLI number
25 received matches one on the stored CLI list, so by agreed
standard procedure the mobile unit 20 does not register
its presence with the new cell C_6. Note that the
received SI code is still the same "A" code. As shown in
Figs. 4 and 5, for mobile unit 20, as presently assigned
30 cell C_6 is indeed in the same virtual location area
originally defined for cell C_7. At this time, the MSC 12
is aware of the mobile unit 20's general location within
the cells of the subset group originally based on cell C_7
and can therefore locate the mobile unit to connect it to
35 an incoming call, for example a call coming from the
public telephone network 32 through a telephone interface
circuit (TIC) 33, by only paging the few cells of the

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virtual group, including cell C_6. Once located,
connection is made through the proper RBS in the usual
manner.

   In keeping with the invention, the mobile unit 20

5   can travel back and forth between cells C_6 and C_7 any
number of times without having to re-register its
location with the system. Likewise, the mobile unit 20
can travel to any of cells C_{11}, C_3, C_4, C_8, C_{12} and C_{16}
without re-registering. In short, only when the mobile

10 unit 20 leaves its virtual location area (the subset
group of cells) and enters a new cell that does not
belong to the previous subset group is any action
required.

   Thus, as shown in Fig. 6, when the mobile unit 20

15 travels to cell C_5, it leaves the virtual location area
originally associated with cell C_7, and at step 102 no
CLI match is found since cell C_5 is broadcasting a CLI
equal to 10 which is not on the $CLI_{(list)}$ stored in the
mobile unit's memory area 26a. Accordingly, at this time

20 at step 112 the mobile unit 20 registers with RBS R_5 its
presence within cell C_5 and receives a new list of CLI
numbers associated with that cell, i.e., CLI = 07 (for
current cell C_5), CLI = 05 (for cell C_6), CLI = 06 (for
cells C_1 and C_2), CLI = 08 (for cells C_9 and C_{13}), and CLI

25 = 09 for cell C_{10}).

   At that time, a new virtual location area is defined
for the mobile unit 20, such as the location area
depicted in Fig. 6. Note that in accordance with the
invention, unlike fixed location areas, the mobile unit

30 in the same system cannot ordinarily repeatedly cross a
boundary into a cell that is not on its list, requiring
registration each time, since once the mobile unit 20
enters an unlisted cell both the current cell and the
previous cell typically become part of its new list. For

35 example, even if the mobile unit 20 immediately reenters
the cell C_6 after previously crossing the boundary into
the cell C_5, no additi nal registration takes place.

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That is because as allocated in this example, cell C_6 belongs to the virtual location area for cell C_7 and also to the virtual location area for cell C_5.

In accordance with another feature of the invention, since different systems of cells (having their own MSC) are often adjacent other such systems such as in Fig. 2, the present invention further provides a procedure to accommodate the system switching situation to minimize the amount of coordination required between the various systems. To this end, properly coordinated adjacent systems are arranged to share identical CLI codes on at least some of their bordering cells. If a mobile unit crosses into a new system having the same CLI, no registration is necessary since the former system is able to indirectly locate the mobile in the other system by communicating therewith. However, to minimize the coordination between systems, the mobile automatically registers with the new system if it enters a second cell of the new system. In this manner, only the CLIs of the border cells need to be coordinated and reserved, and adjacent systems are otherwise free to distribute their CLIs as desired.

To accomplish the system switching, since as previously mentioned, the system identifier (SI) is broadcast along with the CLI number for a cell, the current SI is similarly stored ($SI_{(s)}$) and compared against any subsequently received SIs ($SI_{(r)}$) to determine if the system has changed. Additionally, the mobile unit 20 stores the SI of the system that originally provided the virtual location information ($SI_{(list)}$).

Thus, as shown in Figs. 12 and 13, if at step 104 the SI received does not equal the SI stored, then the mobile unit 20 will overwrite at step 106 the stored SI for the former current cell ($SI_{(s)}$) with the rec ived SI ($SI_{(r)}$) for the new cell before looping back to step 100. As described above, no registration takes place, since this is the first cell of the new syst m that has been

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entered. Nevertheless, the MSC is aware that the mobile
unit might be in a cell of the new system sharing a
similar CLI number as previously coordinated.

Once another cell is entered, if the received SI
5   again equals the stored SI ($SI_{(s)} = SI_{(r)}$), then the
system further checks (at step 108) to determine if the
newly received SI equals the SI of the cell that
originally provided the CLI list ($SI_{(r)} = SI_{(1)}$). This
occurs when the mobile unit reenters the system it is
10   still registered in, for example, by turning around. If
at step 108 the received SI equals the SI of the cell
that provided the CLI list, then no further action is
necessary, since the mobile unit 20 is already
appropriately registered. However, if they are not
15   equal, the mobile unit re-registers with the new cell as
described above, regardless of the CLI number received,
and receives a new CLI list (at step 110) for the new
system. In this manner, the amount of coordination
between adjacent systems is minimized since even if the
20   second cell entered in the different system has the same
CLI number as one of the numbers on the stored CLI list,
the mobile station 20 re-registers upon entering the
second cell of the new system.

Whenever a mobile unit registers in a system, the
25   system determines at step 128 if the mobile unit belongs
to that system, i.e., it checks to see if the mobile is
in its "home" system. If so, nothing further needs to be
done for that mobile, as it has already registered its
location within in a cell and has received the proper CLI
30   list. If however, the mobile unit does not belong, the
"foreign" MSC determines at step 130 if this is the first
time that the mobile unit has registered within its
system. If this is the first time, then the foreign MSC
notifies at step 132 the home system of the presence of
35   the mobile unit therein. If not, the foreign MSC takes
no action since the notification has been previously
performed after the initial registration.

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Within the same system, it can be readily
appreciat d that the various subset groups corresponding
to each cell can be realigned by the MSC according to
system needs. This can be accomplished in a simple
5   manner by having the MSC change the subset groupings by
changing the list and/or the identities of the CLI
numbers corresponding to the cells. For example, by
altering the groupings, a line of cells along an
expressway can be grouped together at rush hour to
10   minimize registrations, and restored at non-peak hours to
a pattern wherein all or most of the cells adjacent the
cell wherein registration occurs are grouped together.
Likewise, smaller cells such as in a downtown area may be
grouped together a first way during working hours and
15   then grouped differently during commuting or weekend
hours. By analyzing the amount of communication traffic
on the system either dynamically or historically, the
system is able to determine if there is an imbalance
between messages from the system to the mobiles and
20   messages from the mobiles to the system on the control
channels, and take appropriate action by realigning the
subset cell groupings to optimize system performance.

For example, the system can reduce the number of
messages transmitted to the mobile units from any cell's
25   control channel by reducing the number of location areas
that include that cell. As a tradeoff, this increases
the number of messages to the system on that cell since
more mobile units will need to re-register upon entering
that cell, as it will be stored in fewer of the CLI lists
30   stored in the numerous mobile units' memories.

Moreover, it is also feasible to define a subset
grouping location area based on the characteristics of
the type of the mobile unit itself, such as the type of
equipment including how much power it has or its
35   modulation. The system can also allocate a virtual
location area stored for each particular mobile unit
based on its type of subscription or its movement

history. If such an arrangement is desired, these
paramet rs are also stored in the MSC memory 16 in
conjunction with the mobile unit identification to make
the virtual location determination.

5   Finally, it is feasible to develop a set of
standards according to the invention wherein the mobile
units themselves contain a predetermined limited number
of virtual location subset groupings in their memories.
When considered together for all of the cells in a
10   system, the individual subset groupings constitute a
predetermined pattern of the subset cells, i.e., a
comprehensive listing of the subset cell arrangement for
each cell of the system. In this embodiment, both the
MSC and the mobile unit have one or more of these
15   predetermined patterns of subset information stored
therein.

          Thus, if the RBS broadcasts a code number informing
the mobile unit that a certain standard grouping is being
used, the mobile unit will not need to receive the subset
20   information through its transceiver, but instead has
access to the information through a previously written
non-volatile memory or the like. In this manner, only
the current cell identifier needs to be broadcast, since
both the MSC and the mobile station would be aware of the
25   standard pattern and know the standard subset cell
grouping (such as the CLI list) for each cell. Of
course, instead of being previously written, the memory
could be initialized with the values of the patterns as
part of its power-up procedure, although to do so would
30   require a substantial amount of data transmission.

          Indeed, multiple standard patterns may be stored,
although a code or the like identifying which of the
standard patterns is currently in use by the system must
be broadcast to the mobile unit. In this embodiment,
35   each cell of the system broadcasts its "A" identity, a
code identifying which standard pattern is being used
(such as standard pattern "001"), its individual cell

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number, and if so organized, its CLI number. It can be appreciated that although a standardized system utilizing CLI numbers as described previously will function equivalently, for simplicity the standardized system

5   described herein refers to cell numbers C_1-C_{34} directly.

Thus, as shown in Figs 14a and 15a, if the mobile unit 20 initially powers-up in cell C_5, upon receiving the system, current cell and pattern information and registering with the system, the mobile unit has stored

10   in a non-volatile subset memory 26b that for cell C_5, when standard pattern "001" is in effect, cells C_1, C_2, C_6, C_9, C_{10} and C_{34} automatically belong in the subset of cells defining the location area. Of course, it is understood that cell C_5 is also in the group, however to

15   preserve memory it is unnecessarily repetitive to store it again. Since pattern "001" is a standard pattern, the MSC 12, which is responsible for selecting the pattern in use, is likewise aware of the grouped virtual location area, for example by incorporating memory map 26b into a

20   reserved section of its memory 16.

Although the RBS does not therefore transmit the virtual location areas to the mobile unit 20, the concept is substantially identical to the broadcasting of the VMLAs in that the mobile unit 20 only registers its

25   location with a new cell when the mobile unit 20 leaves the VMLA established during the previous registration. At that time, the cell identification that is being broadcast will not match its VMLA list, causing the registration procedure to occur as previously described.

30   It can be readily appreciated that such standards may easily be developed despite the numerous differences in system sizes and shapes since mobile units in systems having fewer cells will never receive cell number identities in excess of the cells in that system. For

35   example, even if standard "001" has groupings defined for hundreds of cells, it will still function since on smaller systems (such as the thirty-four cell system of

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the exemplified embodiment) since th se systems will
never broadcast a cell identity above thirty-four.

By changing the standard code and broadcasting a new
code to the mobile units, the mobile units are able to
5   internally adjust their subset list based upon their
current cell. Moreover, by providing a certain standard
code (or by not providing any standard code at all) the
system would still be able to alternatively function by
broadcasting the CLI information for each cell as
10   described above. Thus, as shown in Figs. 14b and 15b, if
the MSC 12 notifies the RBSs R_1-R_{34} that the standard has
changed to a 002, the broadcasting of the new standard
immediately notifies the mobile unit 20 in cell C_5 that
along with cell C_5, cells C_1, C_{10}, C_{14} and C_{18} are in its
15   virtual location area. If the mobile has moved to a cell
that was previously in the VMLA but is no longer as a
result of the change, (such as cell C_2), the mobile unit
20 re-registers as described previously so that it is not
lost to the system.

20   As shown in the vertical grouping arrangement of
Figs. 14c and 15c, numerous standardized VMLA patterns
can be organized and pre-loaded into the memories of
mobile units.

As can be seen from the foregoing description, there
25   is provided a method and system for reducing system
overhead by locating mobile units within a dynamic subset
of cells. The amount of paging is balanced against the
number of registrations necessary to locate the mobile
unit. The method and system locates mobile units within
30   a virtual subset of cells that varies dynamically
according to the current location of the mobile unit
during registration, which may be dynamically broadcast
or previously standardized. Each mobile unit has its own
virtual location in a subset of cells of the system
35   determined by its current location.

Further, a method and system are provided wherein
the system realigns the subset of cells corresponding to

each cell to optimize system needs. The method and
system facilitates location reporting as mobil s travel
between different systems, yet minimizes the coordination
required between different systems of cells when locating
5   mobile units in one of the systems.

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WHAT IS CLAIMED IS:

1.   In a cellular radio transmission system having
a plurality of radio base stations in communication with
a centralized mobile switching center (MSC), each radio
base station (RBS) defining a cell of the system, a
method of locating a mobile unit within a dynamic subset
of all of the cells of the system, the method comprising
the steps of:

transmitting information in each of the cells
in the system that identifies the cell;

receiving the transmitted information at the
mobile unit from a local one of the cells that is the
cell within which the mobile unit is located;

comparing the identity of the local cell with
the identity of a subset of all of the cells stored in a
memory to determine if the identity of the local cell
matches the identity of one of the cells in the subset;
and

executing the following steps if the identity
of the local cell does not match the identity of at least
one cell within the subset of cells:

(1)   transmitting information from the mobile unit-
to the RBS of the local cell that identifies and reports
the presence of the mobile unit within the local cell;

(2)   communicating information from the RBS of
the local cell to the MSC that locates the mobile unit
within the local cell and within the new subset of cells;
and

(3)   updating the identity of the subset of
cells stored in the memory with the identities of the
cells of a new subset that includes the local cell.

2.   The method of claim 1 further comprising the
steps of transmitting information in each of the cells in
the system that identifies the individual subset of cells
associated therewith and receiving and storing the subset
information at the m bile unit.

3.   The method of claim 1 further comprising the step of predetermining the subsets of cells for the individual cells of the system such that each subset of cells corresponding to each cell includes at least one adjacent cell.

4.   The method of claim 1 further comprising the step of storing the identity of the mobile unit and the identity of the corresponding subset of cells in a MSC memory connected to the mobile switching center.

5.   The method of claim 4 further comprising the step of searching for a mobile unit within the system by 1) recalling from the MSC memory the identities of the subset of cells corresponding to the mobile unit and 2) initially controlling only the radio base stations defining those cells to attempt to communicate with the mobile unit.

6.   The method of claim 4 further comprising the step of clearing the identity of the subset of cells from the mobile switching center memory in a predetermined manner.

7.   The method of claim 6 wherein the identity of the subset of cells is cleared from the MSC memory after a predetermined amount of time.

8.   The method of claim 1 further comprising the step of varying the predetermined subset of cells for each radio base station.

9.   The method of claim 8 wherein the subset of cells for each radio base station is varied in dependence on anticipated usage.

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10.   The method of claim 8 wherein the subset of cells for each radio base station is varied in dependence on the type of the mobile unit.

5   11.   The method of claim 8 wherein the subset of cells for each radio base station is varied in dependence on a service subscription corresponding to the mobile unit.

10   12.   The method of claim 1 further comprising the step of clearing the stored identities of the subset of cells at the mobile unit in a predetermined manner.

13.   The method of claim 12 wherein the stored
15   identities of the subset of cells is cleared from the mobile unit memory each time the mobile unit is powered-up.

14.   The method of claim 12 wherein the stored
20   identities of the subset of cells is cleared from the mobile unit memory each time the mobile unit is powered-down.

15.   The method of claim 4 wherein the identity of
25   the mobile unit is cleared from the MSC memory after a predetermined amount of time after the last communication with the mobile.

16.   The method of claim 1 further comprising the
30   step of assigning a common identifier to a plurality of cells in the system for reducing the amount of transmission required to communicate the subset of cell identities.&

&&&17.   The method of claim 2 wherein each RBS has a
35   memory, further comprising the steps of loading from the MSC to each RBS memory the identity of the subset of cells corresponding to the cell defined thereby, and

retrieving the information from the RBS memory of the RBS
that defines th local cell prior to the step of
transmitting the identities of the subset cells to the
mobile unit.

18. The method of claim 1 further comprising the
step of storing in a memory of the mobile unit and a
memory of the MSC at least one predetermined pattern of
the identities of subset cells corresponding to each of
the cells in the system, whereby the subset of cells
corresponding to each local cell is known to the mobile
unit and to the MSC.

19. The method of claim 18 wherein the memory of
the mobile unit and the memory of the MSC have stored
therein a plurality of predetermined patterns of subset
cells for each cell in the system, further comprising the
steps of selecting at the MSC one of the patterns,
communicating a pattern identifier corresponding thereto
from the MSC to each RBS, and transmitting the pattern
identifier from each RBS to the mobile unit.

20. The method of claim 1 having a plurality of
systems, further comprising the steps of transmitting a
system identifier from each RBS of each system, receiving
the system identifier at the mobile unit, and if the cell
identifier matches one of the stored identities of the
subset of cells, executing the steps of:
        comparing the system identifier to a system
identifier stored in a mobile unit memory for the
previous local cell and if there is not a match,
comparing the system identifier to a system identifier
corresponding to the cell having the subset information
corresponding thereto, and if there is not a match:
                (1) transmitting information from the mobile
unit to the RBS of the new local cell that identifies and

reports the presence of the mobile unit within the local
cell; and

　　　　(2)　communicating information from the RBS of
the local cell to the MSC of the new system that locates
5　the mobile unit within the local cell and within the new
subset of cells.

　　　21.　A mobile radio transmission system having a
mobile switching center (MSC) connected to a plurality of
10　distributed radio base stations, each radio base station
(RBS) defining a cell of the system, for communicating
with at least one mobile unit within the cells, the
system comprising:

　　　　a transceiver at each RBS for transmitting
15　information identifying the cell of the RBS;

　　　　a transceiver at the mobile unit for
transmitting information therefrom and receiving the
information transmitted by the RBS of a local cell that
the mobile unit is within;

20　　　　a memory containing identities of a subset of
all the cells;

　　　　a processor for comparing the identities of the
subset of cells in the memory with the identity of the
local cell;

25　　　　circuitry responsive to the comparison by the
processor for:

　　　　　　(1)　informing the RBS of the local cell that
　　　　　　　　　the mobile unit is within the cell, and

　　　　　　(2)　updating the identities of the cells in
30　　　　　　　　the subset of cells stored in the memory;
if the local cell is not one of the cells in the subset
of cells.

　　　22.　The system of claim 21 further comprising
35　circuitry at the radio base station for transferring the
location of the received mobile unit information to the
mobile switching center.

29

23. The system of claim 22 wherein the MSC includes a memory for storing the corresponding subset information in conjunction with the mobile unit identity.

5   24. The system of claim 23 further comprising means at the mobile switching center for receiving a telephone call requesting connection to a mobile unit, processing circuitry at the mobile switching center for retrieving from memory the subset information for the called mobile

10   unit, and circuitry for communicating the request to the radio base stations corresponding to the subset cells.

25. The system of claim 21 wherein each radio base station includes a system controller, and the system

15   controller at each radio base station controls the transceiver therein to transmit subset cell information corresponding thereto to the transceiver at the mobile unit.

20   26. The system of claim 25 wherein the MSC includes processing circuitry and a first modem, the RBS includes a second modem connected to the first modem at the MSC, and the MSC controls the first modem therein to transfer the cell identifying information to the second modem at

25   the RBS.

27. The system of claim 26 wherein the MSC processing circuitry determines the identities of the subset of cells to be sent to mobile units in each cell.

30

28. The system of claim 27 wherein the MSC processing circuitry determines the identities of the cells in the subset of cells sent to a mobile unit based on the cell location of the mobile unit and the equipment

35   type of the mobile unit as recorded in the MSC memory.

29. The system in claim 27 wherein the MSC
processing circuitry determines the identities of the
cells in the subset of cells sent to a mobile unit in a
cell based on the cell location of the mobile unit and
5   the service subscription of the mobile unit as recorded
in the MSC memory.

30. The system of claim 26 wherein the MSC
processing circuitry assigns each cell of the system an
10   identifier corresponding to one or more cells.

31. The system of claim 26 wherein each RBS
includes a memory, and the MSC processing circuitry
communicates to each RBS the subset cell identity
15   information corresponding thereto for storage in the RBS
memory and retrieval therefrom for transmission to the
mobile unit.

32. The system of claim 22 wherein the mobile unit
20   includes a memory and the MSC includes a memory, and the
mobile unit memory and the MSC memory contain data
representing at least one predetermined pattern of the
identities of subset cells corresponding to each of the
cells in the system, such that the subset of cells
25   corresponding to each local cell is known to the mobile
unit and to the MSC.

33. The system of claim 32 wherein the MSC memory
and the mobile unit memory contain data representing a
30   plurality of predetermined subset identity patterns, and
each radio base station includes a system controller and
a modem therein, the MSC includes processing circuitry
and a modem therein, and the MSC processing circuitry
determines which subset pattern is in operation and
35   communicates a pattern identifier to each radio base
station such that the system controller therein controls

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the RBS transceiver to transmit the patt rn information
to the transceiver at th mobile unit.

34.   The system of claim 27 wherein the MSC
processing circuitry further communicates system
identifying information to each RBS connected thereto for
transmission to the mobile unit, the mobile unit
transceiver receives the system identifying information
and the mobile unit processor stores it in the mobile
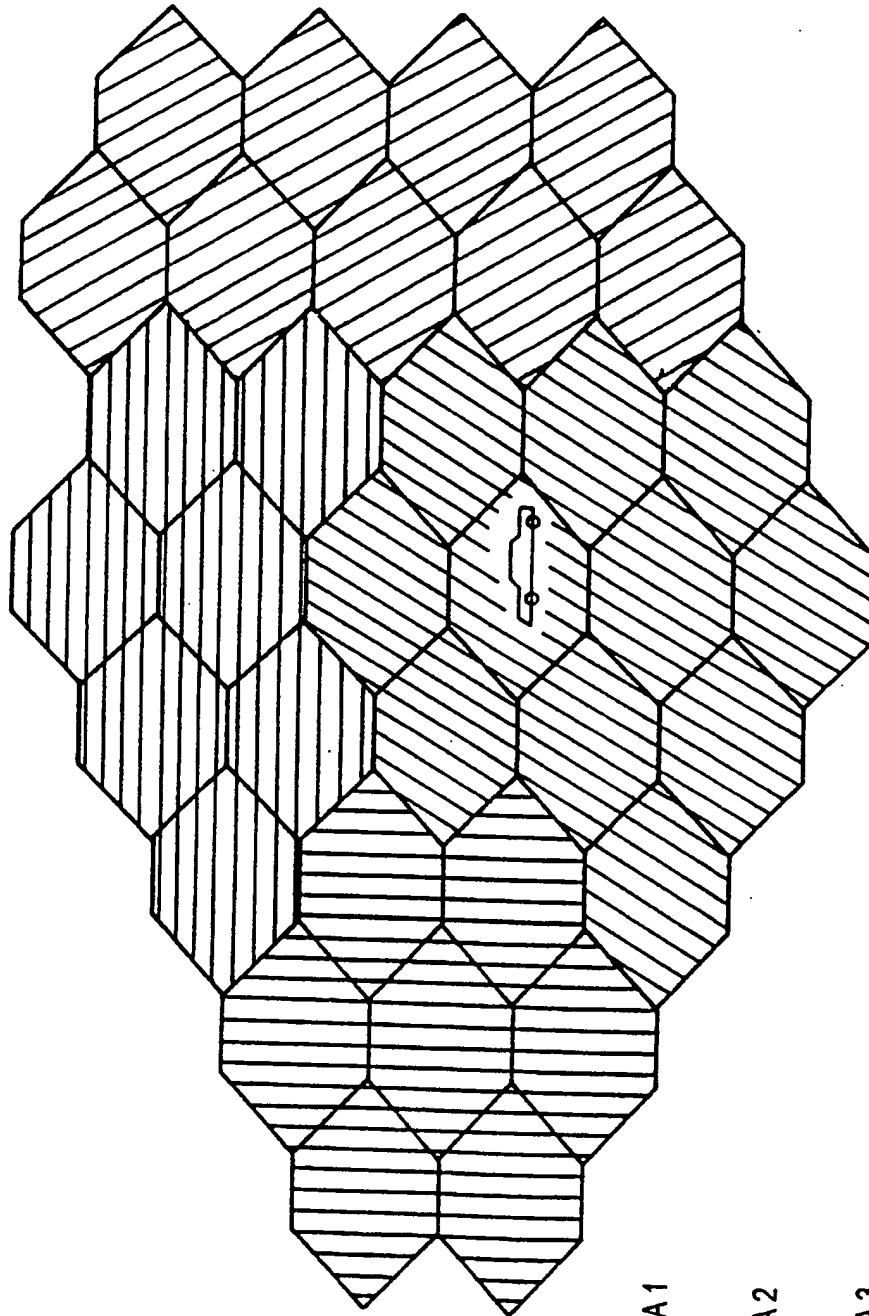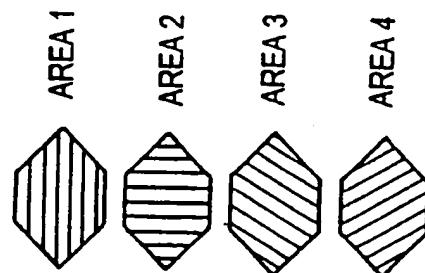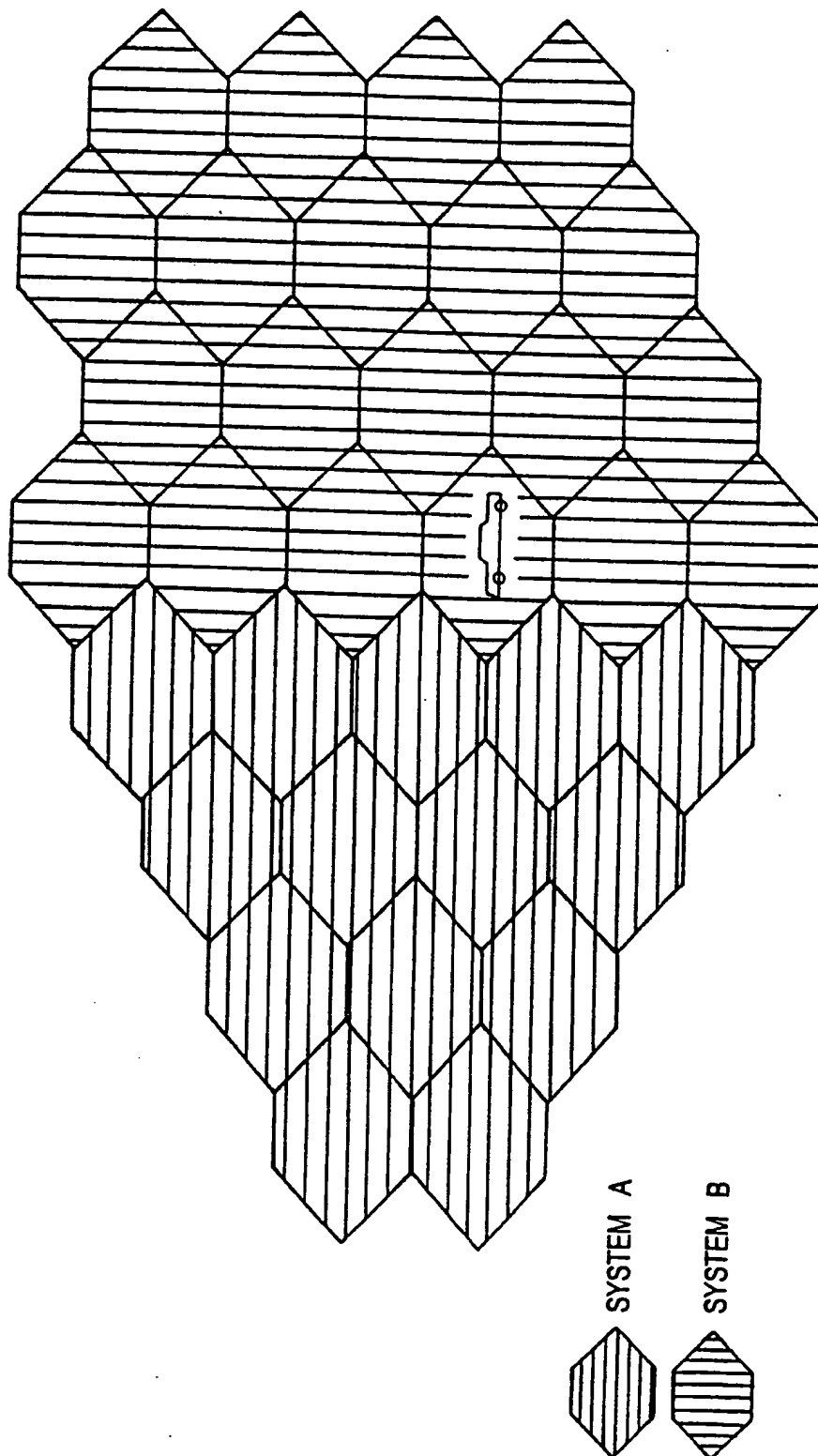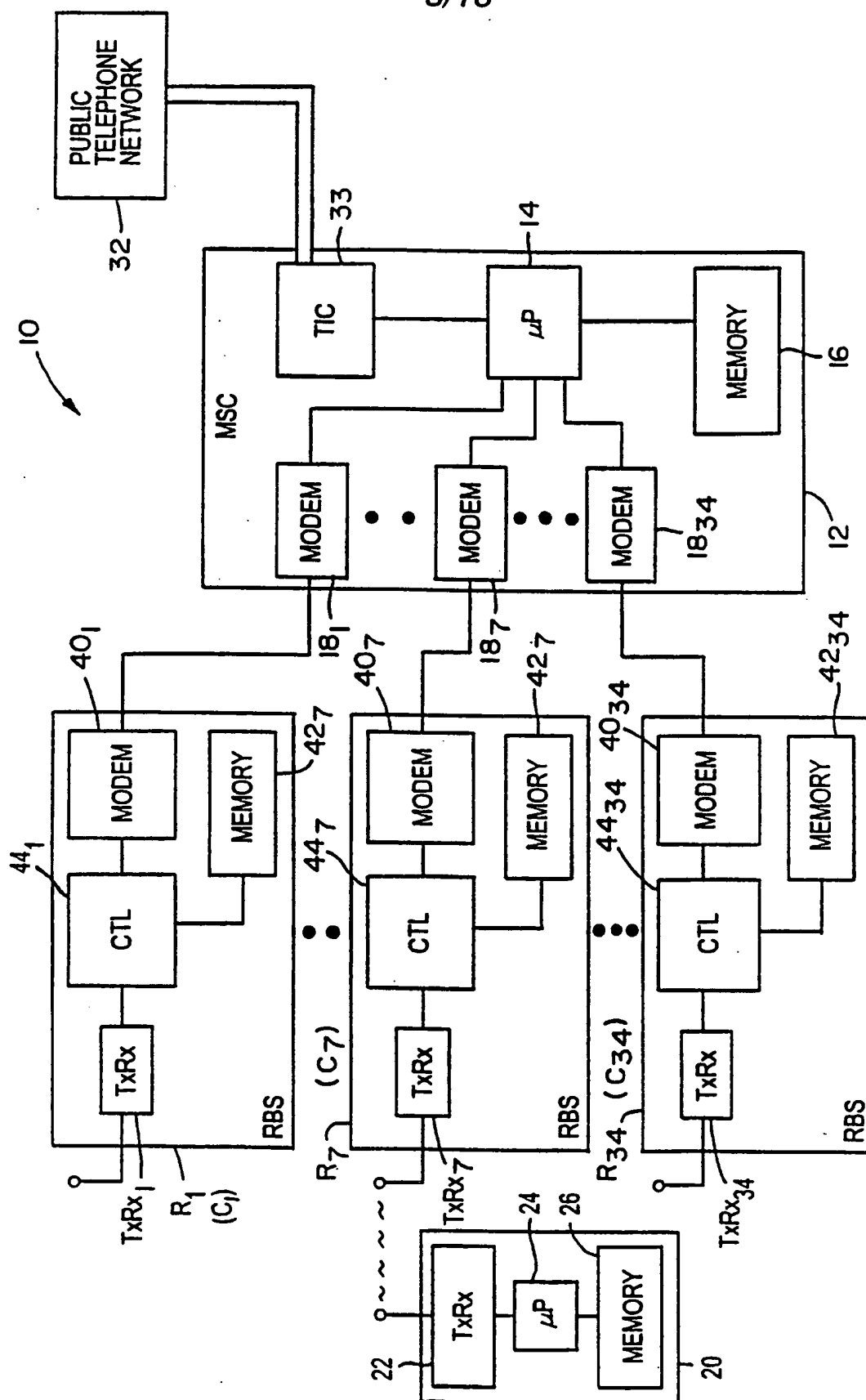unit memory in conjunction with the identity of the local
cell.

FIG. 1
PRIOR ART

AREA 1

AREA 2

AREA 3

AREA 4

FIG. 2

SYSTEM A

SYSTEM B

FIG. 3A

FIG. 3B

FIG. 4

FIG. 5

FIG. 6

16A
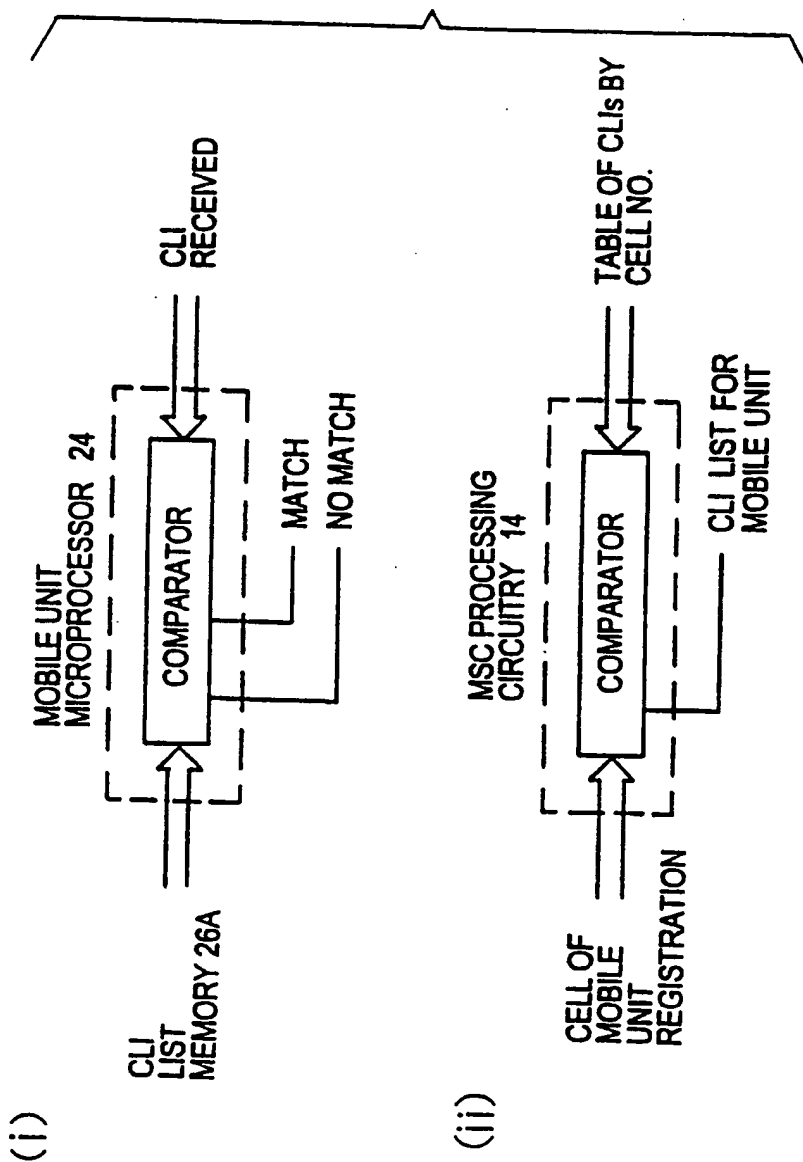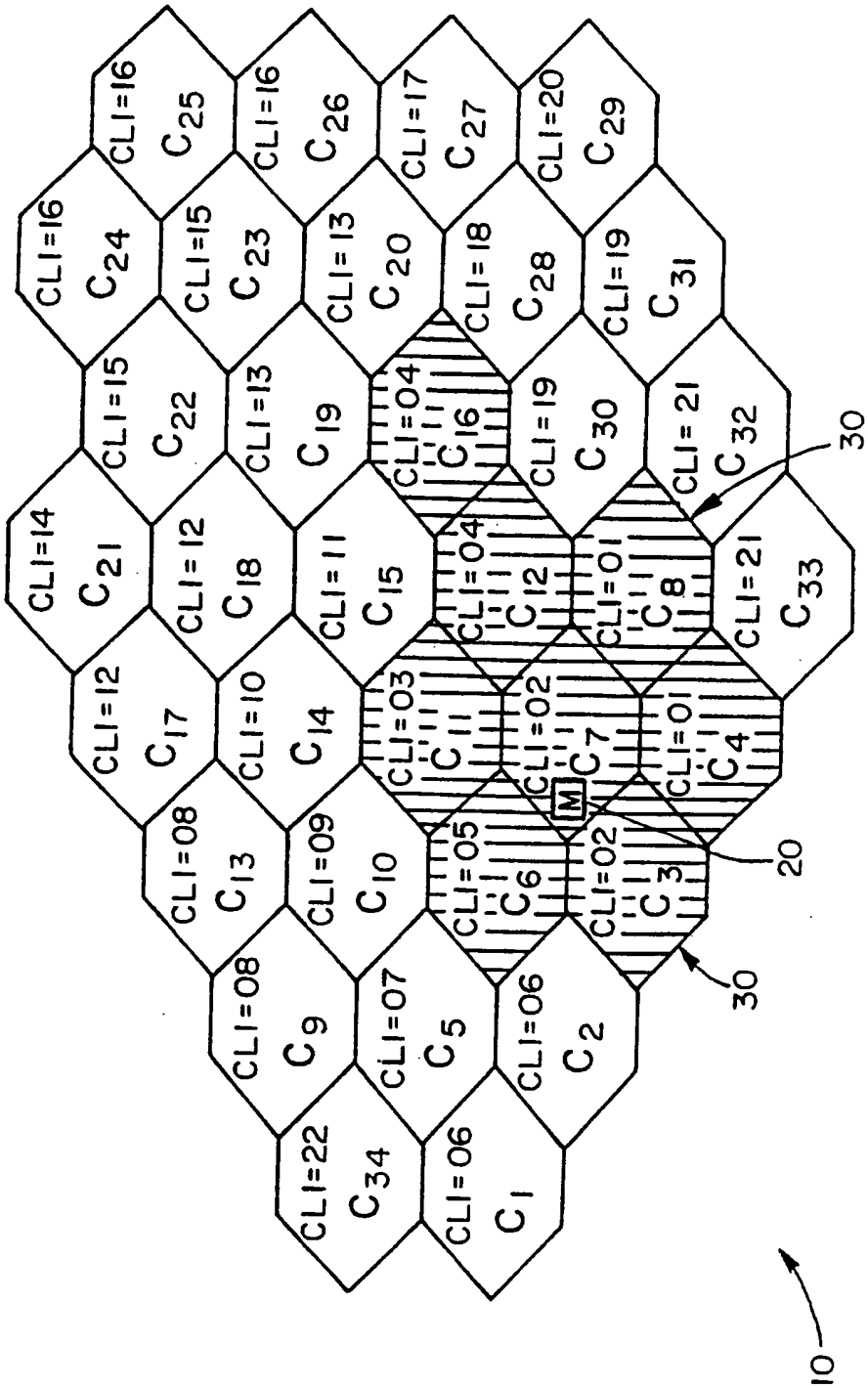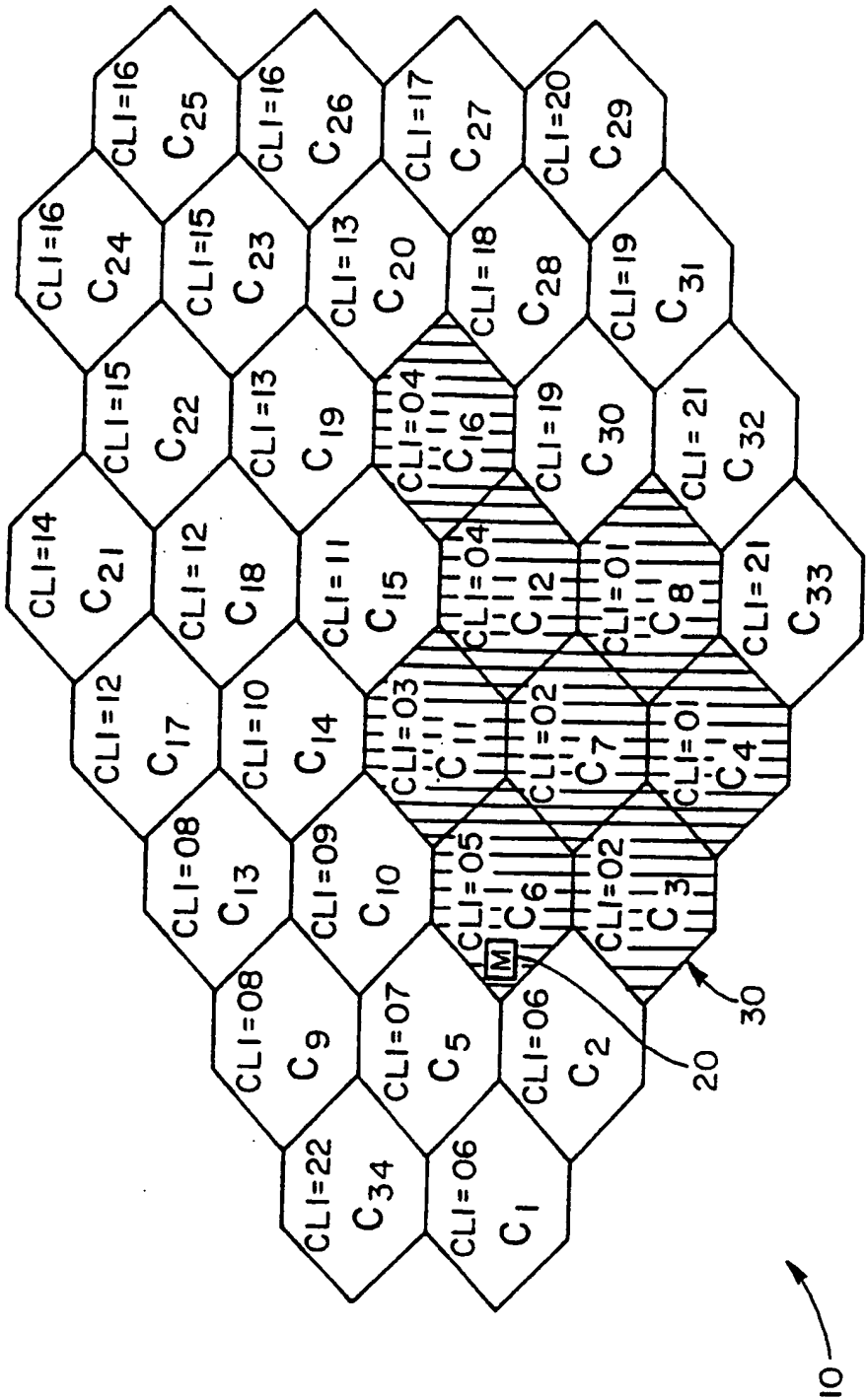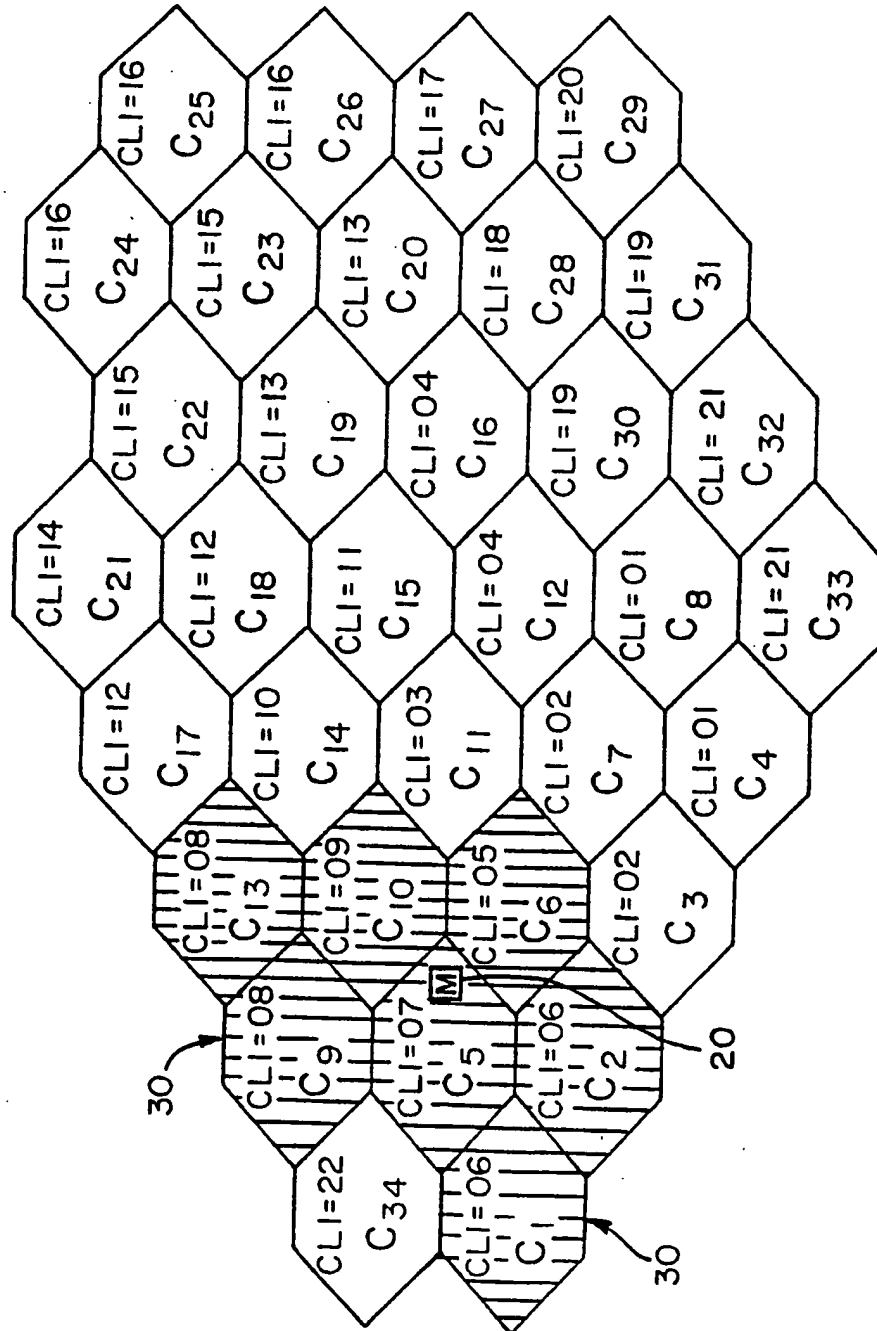
MOBILE ID	VIRTUAL LOCATION DEFINED CELL
M20	C_7

FIG. 7

16B

CELL #	CLI (LIST)
C_1	06, 07
C_2	06, 07, 05, 02
C_3	02, 06, 05, 01
C_4	01, 02
C_5	07, 06, 08, 09, 05
C_6	05, 06, 07, 09, 03, 02
C_7	02, 05, 03, 04, 01
C_8	01, 02, 04
C_9	08, 09, 07
C_{10}	09, 07, 08, 10, 03, 05
C_{11}	03, 05, 09, 10, 11, 04, 02
C_{12}	04, 02, 03, 11, 01
C_{13}	08, 10, 09
C_{14}	10, 09, 08, 11, 03
C_{15}	11, 03, 10, 04,
C_{16}	04, 11

• •   • •

C_{34}	06, 07, 08, 22

FIG. 8

CELL#	SI	CLI BROADCAST
C_1	A	06
C_2	A	06
C_3	A	02
C_4	A	01
C_5	A	07
C_6	A	05
C_7	A	02
C_8	A	01
C_9	A	08
C_{10}	A	09
C_{11}	A	03
C_{12}	A	04
C_{13}	A	08
C_{14}	A	10
C_{15}	A	11
C_{16}	A	04

⋮   ⋮

C_{34}	A	22

FIG. 9

CLI	CELLS
01	C_4, C_8
02	C_3, C_7
03	C_{11}
04	C_{12}, C_{16}
05	C_6
06	C_2, C_1
07	C_5
08	C_9, C_{13}
09	C_{10}
10	C_{14}
11	C_{15}
12	C_{17}, C_{18}
13	C_{19}, C_{20}
14	C_{21}
15	C_{22}, C_{23}
16	C_{24}, C_{25}, C_{26}
17	C_{27}
18	C_{28}
19	C_{30}, C_{31}
20	C_{29}
21	C_{32}, C_{33}
22	C_{34}

FIG. 10

CLI
02
05
03
04
01

— 26

— 26A

FIG. 11

RECEIVE CLI &
SI ON NEW   — 100
CONTROL CHANNEL

102

CLIr = CLI (list)   YES

104

NO   YES   SIr = SIs   NO

108

SIr = SI (list)   YES

NO   106

SET
SIs = SIr

110

CLEAR
CLI (list) & SI (list)

112

END

REPORT LOCATION
TO SYSTEM

114

RECEIVE SI, CLI (list)
STORE CLI (list)
SET SI (list) = SIr

END

FIG. 12

FIG. 13

```
┌─────────────────────┐
│ RECEIVE LOCATION    │
│ REPORT  FROM        │──── 120
│ MOBILE VIA RBS      │
│ (MOBILE ID, CELL ID)│
└─────────────────────┘
           │
           ▼
┌─────────────────────┐
│ SAVE CURRENT CELL ID│
│ OF MOBILE UNIT      │──── 122
│ [IN TABLE OF FIG. 7]│
└─────────────────────┘
           │
           ▼
┌─────────────────────┐
│ GET CLI (list) FOR  │
│ CELL                │──── 124
│ [FROM TABLE OF FIG. 8]│
└─────────────────────┘
           │
           ▼
┌─────────────────────┐
│ SEND CLI (list)     │
│ TO MOBILE UNIT      │──── 126
│ VIA RBS             │
└─────────────────────┘
           │
           ▼         128                      130
        ╱─────────╲      NO        ╱─────────╲      YES
       ╱     IS    ╲──────────────╱   FIRST    ╲──────────┐
      ╱  MOBILE ID  ╲            ╱ LOCATION REPORT╲        │
      ╲ HOME IN THIS ╱          ╲ FROM MOBILE UNIT╱        │
       ╲  SYSTEM    ╱            ╲       ?        ╱         │
        ╲    ?    ╱               ╲─────────────╱          │
         ╲──────╱      YES              │ NO               ▼
            │                           │            ┌──────────┐  132
            │                           │            │ SEND     │
            │◄──────────────────────────┘            │ LOCATION │
            │                                         │ REPORT TO│
            │                                         │ HOME SYSTEM│
            │                                         └──────────┘
            ▼                                              │
         ┌──────┐                                          │
         │ END  │◄─────────────────────────────────────────┘
         └──────┘
```

SUBSTITUTE SHEET

Standard 001	
Cell#	VMLA Additional Cell List
C_1	C_2, C_5, C_9, C_{34}
C_2	C_1, C_5, C_6, C_3
C_3	C_2, C_4, C_6, C_7
C_4	C_3, C_6, C_7, C_8, C_{33}
C_5	C_1, C_2, C_6, C_9, C_{10}, C_{34}
C_{31}	C_{28}, C_{29}, C_{30}, C_{32}
C_{32}	C_8, C_{30}, C_{31}, C_{33}
C_{33}	C_4, C_8, C_{32}
C_{34}	C_1, C_2, C_5, C_9

26B

FIG. 14A

Standard 002	
Cell#	VMLA Additional Cell List
C_1	C_5, C_{10}, C_{14}, C_{18}
C_2	C_6, C_{11}, C_{15}, C_{19}
C_3	C_7, C_{12}, C_{16}, C_{20}
C_4	C_8, C_{30}, C_{28}, C_{27}
C_5	C_1, C_{10}, C_{14}, C_{18}
C_{31}	C_{29}, C_{32}, C_{33}
C_{32}	C_{29}, C_{31}, C_{33}
C_{33}	C_{32}, C_{31}, C_{29}
C_{34}	C_9, C_{13}, C_{17}, C_{21}

26B

FIG. 14B

Standard 003	
Cell#	VMLA Additional Cell List
C_1	C_{34}
C_2	C_5, C_9
C_3	C_6, C_{10}, C_{13}
C_4	C_7, C_{11}, C_{14}, C_{17}
C_5	C_9, C_2
C_{31}	C_{28}, C_{20}, C_{23}, C_{24}
C_{32}	C_{30}, C_{16}, C_{19}, C_{22}
C_{33}	C_8, C_{12}, C_{15}, C_{18}, C_{21}
C_{34}	C_1

26B

FIG. 14C
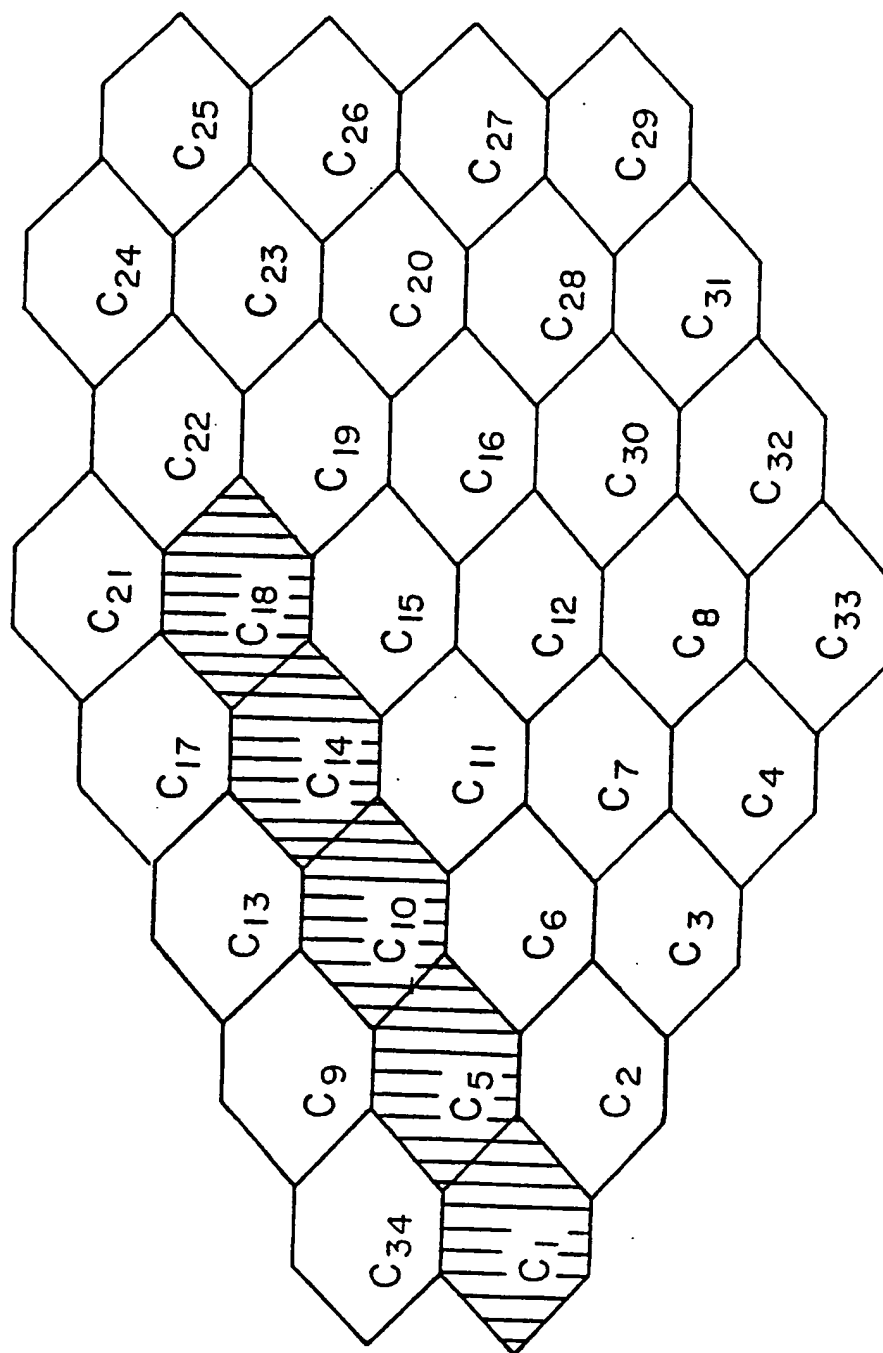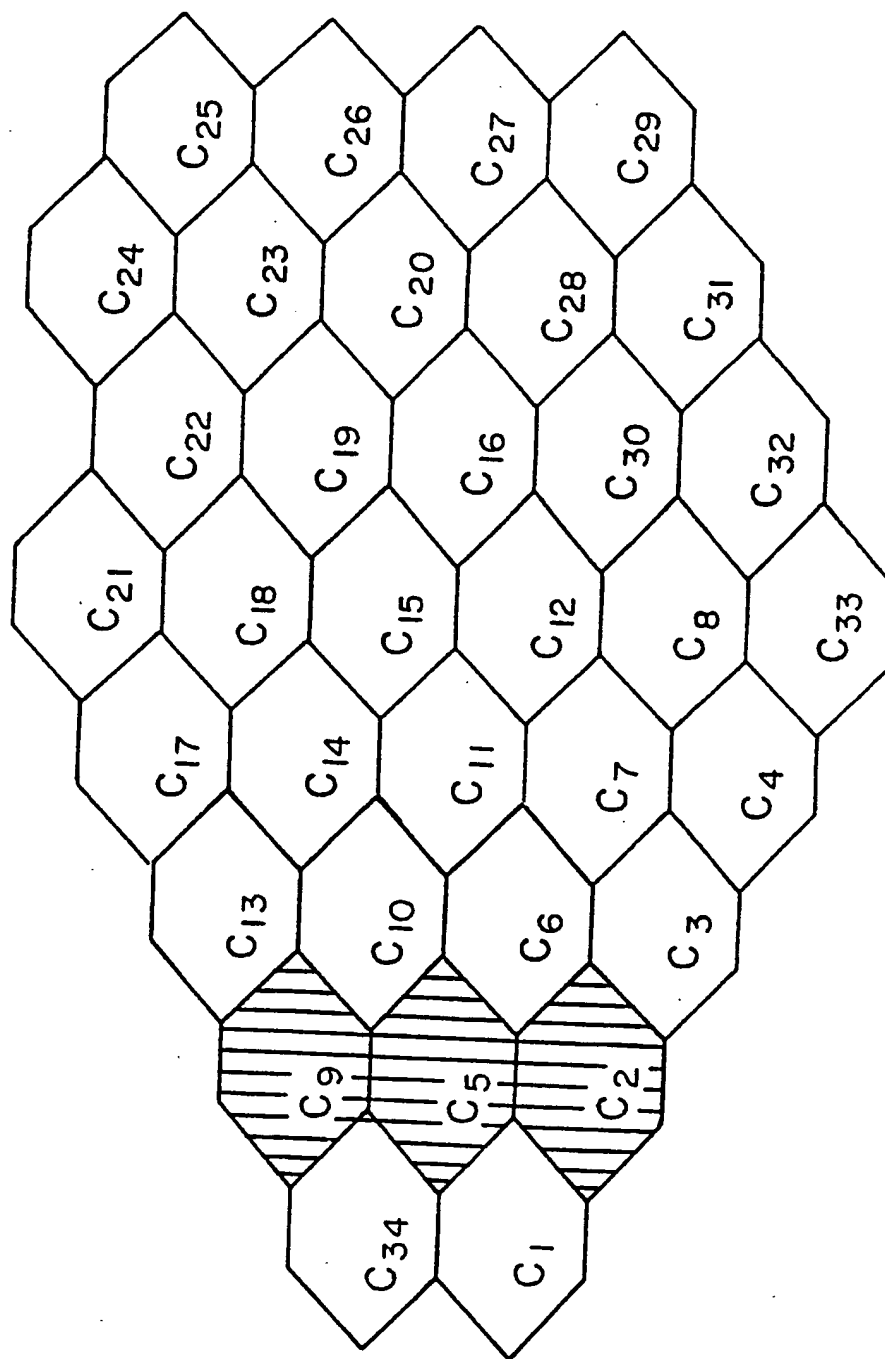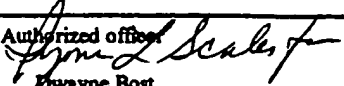
FIG. 15A

FIG. 15B

FIG. 15C

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC(5) :HO4M 11/00
US CL :379/059
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
U.S. : 379/058, 59, 60; 455/33.1, 33.2

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
APS
search terms: cell#, subset#, (mobile or wireless or radio)(w)(telephone or phone), (radiotelephone).

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 4,876,738 (Selby) 24 October 1989; see Abstract; column 2, lines 8-29; column 3, lines 35-50; column 6, lines 35-49; column 9, lines 50-54.	1, 21
A	US, A, 4,916,728 (Blair) 10 April 1990; see Abstract.	1, 21
Y	US, A, 5,189,734 (Bailey et al.) 23 February 1993; see Abstract; column 2, lines 25-37, 44-53; column 3, lines 47-52; and column 4, lines 1-27.	1, 21
A	US, A, 4,737,978 (Burke et al.) 12 April 1988; see Abstract; and column 7, lines 2-12.	1, 21

☐ Further documents are listed in the continuation of Box C.	☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be part of particular relevance		
"E"	earlier document published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
01 March 1994	MAR 22 1994

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